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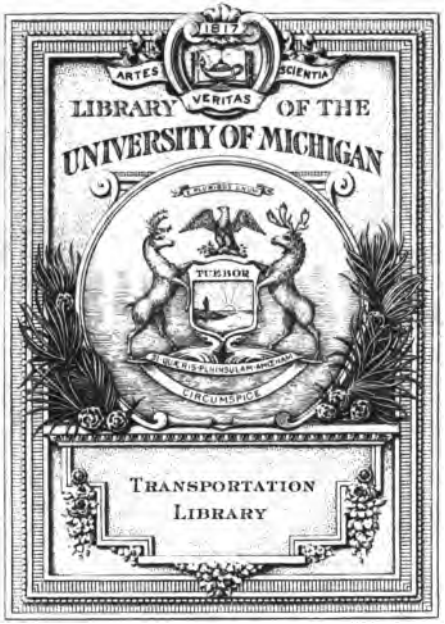
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RAILWAY ECONOMY

AN EXPOSITION OF THE ADVANTAGES OF

LOCOMOTION BY LOCOMOTIVE CARRIAGES INSTEAD OF THE PRESENT EXPENSIVE SYSTEM OF STEAM TUGS.

BY LEWIS GORDON, CIVIL ENGINEER,

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Citius emergit veritas ex errore quam ex confusione.

Baco, *de forma calidi*, Aph. x.

EDINBURGH: SUTHERLAND & KNOX:
SIMPKIN, MARSHALL, & CO., LONDON.

MDCCCXLIX.

selves, may be looked upon as a *machine* for effecting the transport of " passengers" and " goods."

The power of the *steam* is taken up by the *pistons of the engine*, and *transmitted* to the circumference of the driving-wheels, the adhesion of which to the rails gives the *fulcrum*, or point of *reaction*, by which the power is continually transferred by the subsidiary mechanism of wheels, axles, springs, and carriages, to the useful effect to be produced—the *transport of passengers and goods.*

The existing railway machinery will be found to be monstrously disproportioned to the useful effect produced, in four-fifths of the number of times that the machine is put in action. And to this waste of power may be most justly attributed much of the present embarrassment of Railway Companies, whether in respect of their own internal financial position—their position with the dissatisfied public, as respects its pampered expectation of, and their power to supply accommodation ; and, lastly, their position with respect to inability to introduce, what in the opinion of the best judges in the matter, is the main element of traffic, that will conduce to the success of the railway system.

To convey, on the metropolitan railways, a net weight of from six to ten tons of passengers and luggage, at thirty miles per hour, a gross weight of from sixty to seventy tons is usually kept in motion. On provincial lines, the transport of from two to five tons of useful or paying weight involves the keeping in motion a gross weight of from forty to fifty tons.—And to these facts may be traced most of the ano-

malies and imperfections manifest in the railway system as hitherto developed.

To prove these assertions I must, in the first place, enter into an examination and discussion, which shall be as brief as possible, of the facts ascertained on the following points :—

1. What is the present average weight of locomotive engines and tender—what is the amount of the *adhesion*—what is the *power* of the engine —what its *efficiency*, and what is the prevailing opinion on the question of the best form and proportion of the locomotive engine ?
2. What is the average weight of the first, second, and third class carriages and of the trucks ? and what is the average composition of the trains on railways in different districts ? What is the resistance they oppose to the locomotive power ?
3. What is the average weight of passengers and their luggage, per train, on railways in different districts ? What is the efficiency of the railway train as a machine ?

OF THE LOCOMOTIVE.

Mr. R. Stephenson's engine, the "Rocket," was constructed according to the 5th condition on which the Directors of the Liverpool and Manchester Railway, in October 1829, offered "a premium of £500 for the most improved locomotive engine." The weight of the "Rocket" engine was 4 tons, 5 cwt.; its tender, with water and coke, 3 tons, 4 cwts., 2 lbs.

The power of this engine was equal to drawing two carriages, weighing, with load, nine and a-half tons, at fifteen miles per hour.

The immediate successors of the Rocket—the Jupiter, the Vulcan, the Vesta, the Fury, the Leeds, and others, weighed from 7 to 8 tons. The Atlas, made in 1832, weighed 11·42 tons.*

Since these beginnings, the weight of the locomotive has been gradually increased, so that the total weight of passenger engines, on narrow-gauge lines, varies now from eighteen to twenty-five tons, and those on the broad-gauge weigh from twenty-four to thirty-five tons, when charged with water and coke.

The tenders for the narrow-gauge engines, weigh from eight to ten tons when charged, and those of the broad-gauge from twelve to fifteen tons. Thus the average weight of the *locomotive engines and tenders*, now considered the best adapted for railways, may be taken, for the Narrow-gauge, . . 29 tons.

Broad-gauge, . . . 42 tons.

The increased weight of the locomotive is the consequence of the increased size of the boiler, that is, *of the increased power of the engine.* The adhesion of the wheels to the rails being proportional to the weight of the engine, for the same distribution of the weight on the wheels, this requisite has been attained consentaneously with increase of power. Comparing the *weight* of the most modern engines with the older engines, and comparing also the relative areas of their heating surfaces, as com-

* See Wood on Railways, third edition, p. 513, *et seq.*

posed of *fire-grate, fire-box,* and *tubes,* and of their dimensions in respect of diameter of pistons, length of stroke, and diameter of driving-wheels, we find that the *absolute power* of the engine has increased in *a greater ratio* than the absolute weight; and we may therefore conclude that, in the locomotive question, *per se,* it is better to employ *one* heavy engine than two *lighter engines,* to do a given amount of work, with the present mechanism for transport.

With the increase in the weight of the locomotive, the weight of the rails and chairs, and the strength of the whole permanent way of railways, has necessarily been increased, so that the rails, which in 1829 had such a sectional area that they weighed thirty-two pounds per yard, are now of such dimensions that they weigh from seventy-five to ninety pounds per yard. No system will allow of a recurrence to the former light weight of rails, but a considerable saving on the present weight may probably be effected.

The Adhesion of the driving wheels depends on the distribution of the weight of the *locomotive engine alone.* This distribution is—

For Passenger Engines.	On Trailing Wheels.	On Driving Wheels.	On Leading Wheels.
	Tons.	Tons.	Tons.
On the Narrow-gauge,	3 to 4	8 to 13	4 to 6
On the Broad-gauge,	7 to 8	8 to 11	8 to 12 (on 4 wheels)

The *adhesion,* being the *friction between the surface of the rails* and the *periphery of the driving-wheels,* bears a certain proportion to the insistent weight on the driving-wheels, varying with the state of

smoothness, *cleanness*, and *dryness*, of the rails and wheels. Mr. Stephenson* says that the "*adhesion* varies from one-sixth to one-thirteenth of the insistent weight, according to the state of the rails," and that "the amount of adhesion which should be relied on, depends on the weight of the train and the gradients of the line. For example, with a *heavy train* and bad gradients, to provide for regularity, a greater proportion of the insistent weight should be allowed on the driving-wheels, whilst with a *light train* and good gradients a much smaller proportion would be sufficient."

Mr. D. Gooch† cites a particular case in which the adhesion was less than one-tenth of the insistent weight, and adds, "this, however, was in a very unfavourable state of the rails, and we are practically *able to depend upon one-fifth.*"

The distribution of the weight of the locomotive engine on its wheels is not a matter of indifference; for *great inequality* of weight on the wheels leads to excess of oscillatory motion on the springs, and this affects the road or rails much more prejudicially than the dead weight upon the wheels. As a general result of experience, it appears that the adhesion of the present locomotive *is very nicely balanced with its tractive power*, and it appears that there is *frequent inconvenience felt from the adhesion being less than the power, and danger from its being increased at the*

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* Report of the Commissioners of Railways respecting Railway Communication between London and Birmingham—House of Lords: 1848.

† Report, &c.

sacrifice of steadiness of movement of the mass in motion.

The just appreciation of the *power* of the locomotive is an important point to attain for our present object. It seems far from being generally understood or recognised that the modern locomotive engines, at their usual work, are engines giving out from 150 to 500 horse-power.

In a very recent publication by Mr. Weale, the following paragraph occurs, illustrative of the calculation of the *power* of locomotive engines :—

" *To find the horse-power of this engine.*—Multiply the total resistance (of the carriages) by the velocity of the train in feet per minute, and divide by 33,000, which will give the horse-power. At a speed of thirty-five miles per hour the velocity is 3080 feet per minute. Hence total resistance—

$$\frac{562{\cdot}1+3080}{33{,}000} = 52{\cdot}46 \text{ horse-power."}$$

The resistance here alluded to is that arising from the weight, concussions, and atmospheric displacement *by the carriages.* But this represents a very small part of *the power of the locomotive engine,* and is a manner of stating the fact to which alone it alludes, that is very apt to mislead or divert attention from a most important consideration.

The power of the locomotive, like that of any other steam-engine, must be determined from *diagrams,* obtained by a M'Naught's indicator placed on the cylinders of the locomotive.

I am in possession of a great number of diagrams

taken from well constructed modern engines, of both narrow and broad-gauge proportions, which serve to solve this question. The following two synoptical tables demonstrate the truth of the assertion that a locomotive engine, doing its usual, or some specific service, uses the steam so as to produce,

On the narrow-gauge, from 140 to 199 horse-power.

On the broad-gauge, from 75 to 500 horse-power.

NARROW-GAUGE DIAGRAMS OF MM. GOUIN AND LECHATELIER.

No. of the Diagram.	Speed in Miles per Hour.	Mean absolute Pressure in the Cylinder.		Effective Pressure on Piston.	Mechanical effect of Steam on Pistons.
		Motive.	Resistant or Back-pressure.		
		lbs. per sq. in.	lbs. per sq. inch.	lbs. per sq. inch.	Horse-power.
I.	19.26	80.91	35.40	45.50	142
II.	23.55	61.14	24.74	36.60	139
XXVII.	25.29	73.37	35.69	37.68	154
XLVII.	27.09	70.67	34.12	36.54	161
XIX.	29.45	64.84	30.28	33.55	160
III.	34.25	67.95	34.98	32.99	182
V.	24.78	80.20	30.99	49.19	199

BROAD-GAUGE DIAGRAMS OF MR. D. GOOCH.

No. of the Experiments.	Speed in miles per hour.	Mean absolute pressure in the Cylinder.		Effect. pressure on piston.	Mechanical effect produced by steam on pistons.
		Motive.	Resistant.		
		lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	Horse-power.
XXIII.	20	36.79	16.23	20.48	88
VIII.	20	33.19	15.84	17.35	75
XXV.	25	33.84	16.33	17.51	90
VI.	44	44.53	19.29	25.25	225
XXIV.	56	77.76	31.67	46.07	535
XXI.	60	53.75	24.39	29.36	342

The narrow-gauge diagrams are taken at hazard out of fifty-seven *cards* taken from the "Gironde," a

French engine, weighing, with its tender, twenty-six tons, and the others from the cards taken from the "Great Britain" broad-gauge engine, from the Swindon factory.

I shall for the present leave this representation of the actual power of locomotive engines to speak for itself, merely remarking that the difference in the "absolute *resistant*" pressures, in the two cases, arises in great measure, from the diameter of the blast or exhaust pipe in the Gironde being only three inches, while that of the Great Britain is five inches; the diameter of the cylinders being fifteen inches in the Gironde, and eighteen in the Great Britain; the driving-wheels of the Gironde five feet six inches in diameter, those of the Great Britain being eight feet.

The power of the locomotive engines being thus ascertained, we have next to get a clear idea of their efficiency, that is, of the ratio between the power expended and the work done. We shall first ascertain the ratio between the power developed by the steam in the cylinders and the power necessary to effect the traction of a given train of carriages, as exhibited by a *Morins' self-registering dynamometer*. This will exhibit the efficiency of the locomotive as a machine for moving the carriages.

For want of correlative experiments on the narrow-gauge, I am under the necessity of stating the case in the following general terms, as resulting from the experiments of Messrs. Gouin and Lechatelier, by whom the *indicator* and *dynamometer* experiments were not made consentaneously. I have arranged

the indicator experiments that correspond most nearly to the dynamometer experiments, in reference to speed and weight of train, so that a mean of several indicator experiments, varying slightly on either side of the relative conditions of the dynamometer experiments, is the term of comparison in the fifth column, which gives the *absolute tractive power of the engine*:—

NARROW-GAUGE. (UNIFORM MOTION.)

Speed in Miles per Hour.	Weight of Carriages in Tons.	Dynamometric resistance of Carriages, reduced to Level.	Weight of Locomotive and Carriages.	Indicator resistance of Locomotive and Carriages reduced to Level, and to Periphery of Driving Wheels.	Ratio of Dynamometer to Indicator resistance, or, *Efficiency* of Locomotive.
22½	46	354 lbs.	72	1432 lbs.	0·247
23½	41	360	67	1407	0·255
24	41	422	67	1440	0·293
27½	44	616	70	1540	0·4
32	46	609	72	1756	0·364

And, for the broad-gauge, I have taken Mr. Gooch's averages as given in his synoptical tables, for the following cases:—

BROAD-GAUGE. (UNIFORM MOTION.)

Speed in Miles per Hour.	Weight of Carriages in Tons.	Dynamometric resistance of Carriages reduced to Level.	Weight of Locomotive and Carriages, or, Weight of Train.	Indicator resistance of Locomotive and Carriages reduced to Periphery of Wheel, and to the Level.	Efficiency of Locomotive.
20	100	912 lbs.	150	1738 lbs.	0·524
20	50	451	100	1304	0·345
25	50	520	100	1418	0·366
44	50	741	100	2097	0·353
56	100	1812	100	3556	0·510
60	50	1300	100	3278	0·396

These tables demonstrate, that, for the narrow-gauge railway and engine in question, from sixty to seventy-five per cent. of its absolute power is expended or used in keeping the locomotive itself in motion, and this, too, for ordinary speeds and ordinary weights of train; and that for the broad-gauge engines it requires from fifty to sixty-six per cent. of the absolute power of the engines to keep the locomotive in motion.

The above conclusions, which I have deemed it necessary to put forward, so "that those who run may read," and that all may understand them, is, of course, familiar to engineers who have had occasion to reflect on or examine the subject. Messrs. Stephenson, M'Connell, and Trevithick, in answer to the question,—"What proportion of the steam pressure on the piston is employed in overcoming the friction and other resistances of the steam machinery at different velocities?" (evidently taking "steam machinery" to mean locomotive engines,) say,—"The proportion of the whole steam employed in overcoming the *resistances of the engine* varies with every load and every velocity. No fixed proportion can therefore be named as existing in practice. The resistances of the engine with express trains, (consisting of eight or ten carriages, equal to fifty tons,) probably absorb 70 per cent. to 80 per cent. of the whole force of the (effective) steam pressure on the piston, while that with heavy and slow passenger trains, varying from twenty to thirty carriages, is only about twenty or thirty per cent."

To prevent the possibility of confusion of ideas in

interpreting what has been said in reference to the "resistances of the engine," it must be borne in mind that the *effective pressure* is the difference between the mean *absolute motive pressure* in the cylinders and the mean resistant, or *back pressure*, arising from the force necessary to clear the cylinders rapidly of steam, and to cause the powerful blast required.

The facts I have put together also indicate, as might be anticipated, that as the work done, or weight of train drawn, increases, the efficiency of the engine increases; but even in the most advantageous circumstances, there is no indication that any approach to an *efficiency* of seventy-five per cent., alluded to by Mr. Stephenson, is obtained. At all events, such a favourable proportion between the power expended and the work done, is the exception and not the rule. From the data I have examined, it would appear, that for the ordinary passenger traffic on first-class railways, *from fifty-five to sixty per cent. of all the effective power expended is required to move the locomotive itself;* and in railways of small traffic, the modern locomotive absorbs from sixty to seventy-five per cent. of the power developed in the cylinders, or at the periphery of the driving-wheels.

It is now necessary for my purpose, that, having called attention to the amount of the steam power used in moving the locomotive and tender alone, I should endeavour to separate the "steam pressure employed in overcoming the friction and other resistances of the *steam machinery* alone" from the power required to move the locomotive and tender *considered as so much weight of carriages.*

Taking the narrow-gauge table resistances, and subtracting the dynamometric resistance of carriages, reduced to the level, from the indicator resistance of trains, reduced to the level and to the periphery of wheels, we have :—

Loads. Tons.	Speed in Miles per Hour.	Resistance of Locomotive and Tender alone.	Resistance of a weight of ordinary Carriages equivalent in weight to that of Locomotive and Tender.	Friction and other resistances of Steam Machinery deduced by subtracting the two last columns.	Total power of Engine.
46	22½	1078 lbs.	208 lbs.	870 lbs.	1432 lbs.
41	23½	1047	228	819	1407
41	24	1018	268	750	1440
44	27½	924	364	560	1540
46	32	1617	364	758	1706

It is impossible, from any analogy, to conceive that in so perfect a piece of mechanism as the locomotive *steam engine*, so large a proportion as the fourth column gives, of the total power of the engine, is consumed by *the friction of the steam machinery*. This friction is proportional to the power the engine is exerting, *cæteris paribus;* but cannot reasonably be supposed to bear so large a ratio to the total power, as the above method of deduction indicates in the case of the Gironde. I believe, however, that the power required to drive the locomotive and tender, may be most satisfactorily accounted for by the resistance that the *stiffest railway* now in use, opposes to the motion of the heavily loaded wheels of the locomotive—the driving-wheels, five and a half to six feet diameter, bearing from ten to twelve, or even thirteen to fourteen tons weight, and the leading and trailing-wheels four to six. Each pair

of the wheels of the *carriages* does not bear more than two tons at the utmost. The deformation of the rails increases as the insistent weight on the wheels passing over them, and therefore the part of the resistance of trains, due to the road's surface yielding, to concussions, oscillations, and their concomitant losses of *vis viva*, must be much greater, in proportion to their absolute weight for the locomotives, than for the carriages. The same remark applies to the *friction* of the locomotive as a carriage; for, the difficulty of continuous *lubrication* increases as the insistent weight on the bearings increases, and *the state of the lubrication is an essential element in the amount of the friction.*

In Mr. Gooch's analysis of the experiments made on the broad-gauge, with a view to separating the resistance of the engine and tender, considered as carriages of an equal weight, from the friction of the working part of the engine, he considers that he has ascertained: first, that the friction increases nearly as the load, for the same engine; secondly, that the friction of a small engine is proportionally much greater than that of a large one. The proportion of the total power of the engine involved in Mr. Gooch's *estimate of friction of the working parts of the engine*, made in the same manner as the estimate above given for the case of the Gironde, is much less than in that case, and nearly conformable to what analogy of other steam engines would suggest. This result we attribute mainly to the better distribution of the weight, as well as the less absolute weight, on the wheels of the broad-gauge locomotive

—to the greater stiffness of the Great Western Railway, in proportion to the insistent weight, than on most narrow-gauge lines, and to the circumstance of the driving-wheels of the Great Britain being eight feet in diameter, those of the Gironde being five feet six inches. Thus the resistance of the locomotive, considered as an equal weight of carriages, is approximated by Mr. Gooch much more nearly to the truth, though the process of calculation be deficient, than in my estimate for the Gironde. It is also essential to bear in mind, that the experiments with the Gironde were made while it was doing its ordinary service on the Paris and Orleans Railway, while those on the Great Britain were made *only* in the most favourable circumstances of weather, state of rails, and form of line. Finally, then, in reference to this point, I adopt Mr. Brunel's* view, when he says,—"The amount of the effective pressure on the piston employed in overcoming the friction and other resistances of the steam machinery, is very difficult to estimate. It is, however, *evidently very small;* and when the engine is doing work, it is very nearly in direct proportion to the amount of power exerted by the engine. It is rather less with large engines working below their power than with smaller engines which are forced—a result observable in all machinery." And I further consider that the immense excess of power of the steam in the cylinders, over that shewn by the dynamometer to have been expended in the *traction of the train*, is mainly to be put to the resistance of the

* See Report to House of Lords, quoted above.

locomotive as a carriage, having an excess of weight on a road surface insufficient for such weight, though more than sufficient for any other part of the mechanism of transport.

Before concluding this part of my subject, it is important that I should show as briefly as possible the state of opinion on the economics of the locomotive engine among the more distinguished engineers of *experience* in this matter.

Mr. Stephenson, in his advocacy of the locomotive system as compared with the atmospheric system, said, " We do not make engines heavy for the purpose of obtaining *bite* upon the rail—they are made heavy for the purpose of obtaining *great power*, not for the purpose of getting adhesion." Since this period Mr. Stephenson's practice has been to increase the *power* of the engine, regardless of the necessary concomitant increase in the weight on the driving-wheels. Mr. Stephenson is generally acknowledged to be the best builder of locomotive engines, and his practice may be looked upon as the type of that of other locomotive engineers. Mr. D. Gooch, the responsible agent of the locomotive manufactory of the Great Western Company at Swindon, distinctly states his opinion in nearly the following terms.—It is a very common belief amongst those who are not practically acquainted with the working of locomotive engines, " that if a light train has to be worked it can be cheaper done by a small engine than by a large one ; that putting a large engine on a light train is an extravagant waste of power." This is altogether an erroneous opinion, arising from engines on the

narrow-gauge lines having been made most disproportionately expensive in working. On the broad-gauge the larger engines are the most economical. Without following Mr. Gooch through all his reasonings on this matter, I shall here only inform my readers that the larger engines alluded to are those of which the diagram-results are given in our Table, page 10, and that the weight upon the driving-wheels of these "larger engines" is only ten tons eighteen hundredweight, that on the driving-wheels of the smaller engines being eight tons eight hundredweight, a difference that could not reasonably be expected to affect deductions as to the consumption of fuel by the method of *averages*, which is the test referred to by Mr. Gooch as corroborative of his opinion.—See for some further illustrations of this matter, Appendix, No. II.

Mr. Brunel's opinion, in 1845, was, "that to attain high speeds the locomotive engine must bear a very large proportion in weight to the weight of the whole mass moved. To go fifty to sixty miles per hour, on moderately good gradients, the locomotive engine must weigh half the whole weight of the mass moved—certainly in the present construction of locomotives this is the case."

I might multiply evidence to show that the engineers most conversant with locomotives have overlooked or neglected to look for the facts above adduced, and were consequently quite unprepared for a recurrence to *locomotive carriages* as a means of saving the credit of the railway system.

OF THE CARRIAGES, TRUCKS, &c.

The question of the efficiency of the modern locomotive engine being thus ascertained, by the best facts extant, let us examine the present machinery of carriages, waggons and trucks, in reference to their efficiency, that is, as to the proportion their weight bears to the weight of the net loads they serve to transport.

The average weight of narrow-gauge carriages in Britain, &c., is very nearly as follows :—

	Tons.	Cwts.	Capacity.
First Class, . .	4	5	18 passengers.
Composites, . .	4	5	22 „
Second Class, .	3	15	24 „
Third Class, . .	3	15	24 „
Trucks, . . .	3	0	3 tons.
Horse Boxes, . .	4	0	
Goods Waggons, .	3	5	3 „

All having three-feet wheels.

The average weight of a set of wheels and axles for these carriages is twenty-two hundredweight, of which the wheels weigh about twelve hundredweight.

The average weight of carriages for the broad-gauge is as follows :—

	Tons.	Cwts.	Capacity.
First Class, . .	7	9	32 passengers.
Second Class, .	7	4	72 „
Third Class, . .	7	5	72 „
Royal Mails, . .	7	3	0
Goods Waggons, .	5	5	6 tons.

All having four-feet wheels.

Taking eleven passengers with their luggage as one

ton of weight, it appears that on the narrow-gauge the *absolute efficiency* of the carriages is represented by—Eight tons of passengers and luggage transported by nineteen tons of insistent weight of axles, frames, springs, and carriage-bodies;—or, *sixty-six per cent., at least, of the whole train must be dead weight.*

For the broad-gauge, the same mode of estimating shews that fifty per cent., at least, of the whole train moved must be dead weight.

In the Goods department, the ratio of the absolute weight of carriages to their *tonnage capacity* is nearly the same. Fifty per cent. of the gross load must be dead weight.

Inasmuch, however, as in the usual mode of conducting traffic on railways, the whole capacity of the carriages composing a train is but rarely brought into requisition, the above figures by no means represent the *relative efficiency* of the modern "*train*" as a transporting machine.

There is no branch of railway statistics on which it is more difficult to get exact information than on the *composition of trains* in respect of the ratio of filled and empty places in the carriages—that is, in respect of the number of miles the carriages travel, and the number of passengers carried.

The "statistical returns of the Railway Commission" are deficient in respect of the two elements on which to base any sound calculations as to the cost of railway traffic, viz.,—What is the number of carriages, trucks, &c., of all kinds in use, and what the distance they have run? And, again, What is the number of locomotives in use, and the distance they have run? There are many railway companies who

do not even keep books showing the *miles run* by the different classes of *passengers*. In the private accounts of the locomotive departments of some railway companies, the miles run by each and all the locomotive engines appears to be accurately kept; but the time during which the locomotive is in use, that is, consumed in the process *of getting up steam, and at stations*, is not kept, and here an element of consumption or expenditure of great importance is lost sight of, or debited to the wrong account. The statistical accounts kept by the Belgian and certain French railway companies would serve as models in this respect to railway managers desirous of ascertaining exactly the *elements of the cost of production* for the different elements of transport.

Having, in reference to my present inquiry, gone through a detailed analysis of the "Statistical Returns" of the Railway Companies, made under the 3d and 4th Vic., cap. 97, I find, that after getting rid, by simple filtration, of what appears to me to be nothing more than a mass of *blundering and confusion*, there is scarcely a trace of available information remains.

I have, therefore, had to rely upon a collection of statements, made at various times during the last four years, before Committees of the House of Commons and before Commissioners of Inquiry, for the facts from which I have drawn the general conclusion, that on the metropolitan or great trunk narrow-gauge lines of greatest traffic, the average number of carriages composing trains travelling above twenty miles per hour, is ten—the average number of passengers is under a hundred. The average number of dispatches from the main station lines

being eighteen per day each way. The average distance travelled by all passengers under fifty miles.

For the provincial lines of the Lancashire and Yorkshire district, where the traffic is more *split*, the composition of the *trains* in respect of carriages is nearly the same, and the average number of passengers is reduced to from seventy-five to eighty per train—the average number of dispatches from each main station being twelve per day each way. The average distance travelled by each passenger is under thirty miles.

For the northern provincial lines the average number of carriages is seven, and the average number of passengers fifty. The average number of dispatches being nine each way per day, and the average distance travelled, under twenty miles.

Assuming that these facts are near approximations to the truth, I conclude that the weight of the mechanism of transport, and the weight transported, are, on the average, as exhibited in the following Table:—

TABLE OF RELATIVE EFFICIENCY OF RAILWAY MECHANISM.

Class of Railway.	Weight of Locomotive and Tender.	Insistent weight of Carriages and Luggage Van.	Total weight of the Mechanism of Transport.	Weight of Passengers and Luggage, 11 to a Ton.	Ratio of weight of Passengers to weight of mechanism of transport.	Insistent weight on each Driving-wheel.
	Tons.	Tons.	Tons.	Tons.		Tons.
Great trunk narrow-gauge lines, . .	25	32	57	9	1 to 6½	6
Lines in provinces of densest manufacturing population, . .	25	32	57	7	1 to 8	5½
Lines in less populous districts, . .	22	22	45	5	1 to 9	5

It may be concluded also, that the number of dispatches per day on the main lines of greatest traffic is not more than one train at each interval of fifty minutes, from six, A.M., to nine, P.M.; and on the other main lines there are respectively one dispatch every seventy-five minutes, and one every hundred minutes.

I altogether omit the consideration of the *local trains* and metropolitan railways, such as Greenwich, Woolwich, Blackwall, Bristol and Bath, Bristol and Gloucester, North Shields, South Shields, Glasgow and Paisley, &c., as also that of the long *express trains*, because I have not the facts regarding their traffic with even the probable accuracy that I have them for the others. Nor are these facts of much value to my present object. I may state, however, that the average number of passengers on the Blackwall line is under forty per train. On the Eastern Counties Woolwich line, it is not more than thirty-six passengers per train. On these lines trains are dispatched fifty-four and thirty times per day, respectively. Every quarter our on the one—every half-hour on the other.

These figures indicate the small portion of the mechanism of the railway system of transport that is actually brought into requisition, even on the most frequented lines. Thousands, nay, millions of miles, are run by locomotives and carriages, on the present system, whilst they are performing an amount of transport of passengers preposterously disproportioned to the power and capacity of trains employed for effecting it.

I remember, in December 1836, to have travelled

from Leamington to London—the only passenger in or on the coach throughout the journey. There was snow on the ground; the coach was supplied with changes of six horses at every stage—the speed was ten miles per hour. This was a rare occurrence, no doubt, but compared with the proportions of useful effect accomplished by the present railway locomotive system, on the *average*, the coach, with *six horses, on the turnpike road*, was an excellent adjustment of *power* to *work done*. The weight of the coach and horses was not more than nine times the weight of the coachman, guard, and passenger. The weight of a locomotive, tender, and carriages, forming an express train, is, to the average number of passengers, as fifteen to one at the least ratio, and in the best possible *composition* of trains the ratio of the weight of the motive power and carriage to the passengers carried, is only in the ratio of five to one. Considering, now, that the resistance to motion of a mail-coach, on a first class road, with snow on it, is at the very least sixty pounds per ton of the weight of the carriages, while the resistance of carriages on railways is at the very most twenty pounds per ton, it is astonishing (especially now that we see our way out of the mistake) that the present system of conducting railway passenger traffic should have gone on till it has reached the state of malorganisation which has suggested the recurrence to *steam carriages*, with the application of which on roads Mr. Hancock and others had made excellent progress just as the railway era commenced.* How the applicability of these

* See Appendix I.

carriages on railroads was missed to be perceived, it is not, perhaps, difficult to understand. We shall not, however, enter on that subject, but proceed now to an examination of the RAILWAY LOCOMOTIVE CARRIAGES as constructed by Mr. Adams of Fairfield, and actually in use. I shall examine,—

1st, Their capabilities as to *power* and *capacity* for passengers.
2d, Their relative efficiency.
3d, Their applicability.
4th, Their relative economy.
5th, Their relative safety.

" The *power of the locomotive engine*, supposing the power to be absorbed, may be taken to be directly as the area of the fire-grate, or the quantity of fuel contained in the fire-box." This law applies only when the proportions of the boiler are such as to insure practically the absorption of the heat generated. We have nothing, for the present, to do with the absolute cost, in coke, of the *power* obtained ; that is, we have not for the present to complicate the consideration of the power of the locomotive with the consideration of the power required to blow the fire, important as this question is in the general question of locomotive power. The question for the moment is, can the locomotive carriage boiler be duly proportioned according to the best modern practice ?

The following Table shows the proportion of fire-grate and sectional area of tubes of recent engines, including the Fairfield narrow-gauge LOCOMOTIVE

CARRIAGE, and the proportions of the diameter of the blast-pipe.

Name of Railway.	Area of Grate.	Sectional Area of Tubes.	Proportion of Sectional Area of Tubes to Grate.	Proportion of Blast Pipe's Area to Cylinder.	Area of Cylinder.
	Sq. feet.	Sq. feet.			
Gt. Western, 8-wheeled Engine,	21	5·8	3·⅛	1·⅛	254·4
South Western,	10·4	2·7	4·⅛	1·¼	154·9
Grand Junction,	10·0	2·3	4·⅜	1·¼·⅜	154·9
Engine A, made for experiments at York,	9·7	1·7	5·⅞	1·⅞·1	176·7
Locomotive Carriage,	4·75	1·4	3·½	2·⅝	50·3

It is hence manifest that the new machines' boilers are as well proportioned as the best boilers in use.

"The best engines now in use on the narrow-gauge lines are evaporating 200 to 230 cubic feet of water per hour." The evaporation in the locomotive is certainly 7½ lbs. water per 1 lb. coke; therefore, the coke consumed per hour is 1784 lbs. Taking the area of the narrow-gauge grates as 10 square feet, there appears to be 178 lbs. of coke consumed per square foot of fire-grate per hour.*

Assuming that the new engines will have *draught* sufficient to consume 178 lbs. of coke per square

* It is perhaps worth noting here, that in ordinary low pressure boilers the evaporation is generally under 20 cubic feet of water per hour; and in the most economical boilers it is not more than 15. The quantity of coal consumed per square foot of grating, varies from 20 lbs. down to 6 lbs. Now, to create the draught for ordinary steam fires, nearly 20 per cent. of all the heat is used. The enormous consumption of steam or heat to maintain the draught necessary to consume 178 lbs. of coke per square foot per hour—equivalent to nearly ten times the maximum above mentioned, need not surprise us.

foot of fire-grate per hour, we can with perfect security predict every circumstance as to their power. We shall further assume, that the steam in the boiler is to be maintained at a pressure of 150 lbs. per square inch, or 10 atmospheres in the cylinder.* Supposing, now, that the *back-pressure*, that is, the power required to overcome the inertia of the steam, to which a great velocity has to be communicated—the losses of *vis viva* in the *ports* and *bends*, and the friction in the blast-pipe, consumes 45 per cent. of the whole power generated, there remains, as *effective pressure* in the cylinder, 80 lbs. per square inch. This large allowance of 45 per cent. is consistent with the experimental results obtained from the Gironde, by Mr. Lechatelier, though it amounts to nearly double Mr. Gooch's results from the Ixion and Great Britain broad-gauge engines.

The weights of the narrow-gauge locomotive carriages already constructed are as follows :—

	Cwts.	lbs.	Tons.	Cwts.	qrs.	lbs.
Boiler,	57	30				
Underframe,	59	60				
Body of Carriage,	30	0				
Machinery,	20	0				
Water Tanks,	3	94				
Water,	20	72				
Coke and Box,	5	60				
Wheel Covers,	2	0				
Driving-Wheels and Axle,	22	56				
Leading and Trailing-Wheels,	25	12				
	246	38	= 12	6	1	10
37 Passengers, with Luggage, at 11 passengers per ton,	67	28	3	7	1	0
			15	13	2	10

* See Appendix III.

Or the total weight of the LOCOMOTIVE CARRIAGE on the rails is $15\frac{3}{4}$ tons.

The principal dimensions of the narrow-gauge locomotive carriages are as follows :—

	ft.	in.	
Diameter of Cylinders, . . .	0	8	
Length of stroke, ...	0	12	
Boiler—length, ...	5	0	
... diameter, ...	2	6	
Firebox—outside, ...	2	$10\frac{1}{2}$ × 2 6	
... inside, ...	2	$4\frac{1}{2}$ × 2 0 × 3	1 deep.
Tubes, 115 of $1\frac{1}{4}$ inches in diameter,	5	3 long.	
Heating surface of Firebox, . .	26 square feet.		
Do. do. Tubes, . .	220 do.		
Driving-Wheels, ...	5 feet diam.		
Carrying-Wheels, ...	3 feet.		
Distance between Centres, . .	25 feet.		

The distribution of the weight on the wheels of this carriage is,

Leading-Wheels.	Driving-Wheels.	Trailing-Wheels.
4 tons.	$6\frac{1}{2}$ tons.	5 tons.

Taking the adhesion at one-seventh, it would be sufficient, in this distribution of the weight, to transmit a traction or tractive effort of 1030 lbs. at the periphery of the driving-wheels—which 1030 lbs. is the traction of 80 lbs. effective steam pressure on eight-inch cylinders, with one foot stroke, *reduced* to the periphery of driving-wheels five feet diameter. *The resistances* to motion of this locomotive carriage to be overcome by the steam, may, I conceive, be taken without hesitation as little above that of an equal weight of ordinary carriages, because little weight is brought upon the driving-wheels beyond the weight resting on the wheels of ordinary car-

riages. Although the only accurate dynamometrical experiments on the resistance of trains on the narrow-gauge, in my possession, show that the "narrow-gauge formula" of Mr. Scott Russell, or that of Mr. Harding, errs greatly in *excess* of the true resistance of the *train*, I shall assume that that formula will represent the resistance of the LOCOMOTIVE CARRIAGES as carriages, and this I do in confidence that the results will more probably err in excess than in deficiency. On this assumption has been constructed the following

TABLE OF THE RESISTANCE OF THE LOCOMOTIVE CARRIAGE AT DIFFERENT SPEEDS, AND OF THE RELATIVE POWER AT COMMAND.

Speeds in miles per hour.	Friction Resistance in lbs. per ton.	Atmospheric resistance for assumed frontage of 60 sq. feet.	Total external resistance to carriage.	Add ½ of these for *internal resistance other than the blast power*, to give total resistance of carriage.	Surplus tractive power available.	Weight of steam required per minute, supposing *no expansion*.	Weight of Coke required to be consumed per sq. foot of grate per hour.	lbs. Coke consumed per mile.
						lbs.	lbs.	
20	12·6	60·0	255	306	725	16·84	26·	6·1
24	14·0	86·4	303	364	660	23·18	40·	7·33
28	15·3	117·6	354	425	605	30·66	52·	9·2
32	16·6	153·6	410	492	538	40·0	68·	10·0
36	18·0	194·4	473	568	462	50·0	85·	11·1
40	19·3	240·	539	647	383	60·0	96·	11·5
44	20·6	290·	609	731	299	75·7	120·	12·8
48	22·0	335·	676	811	219	86·5	147·	14·2
52	23·3	405·	765	918	112	109·0	178·	16·0
56	24·6	470·	851	1021	8	.....	.....	...
60	26·0	540·	943	1131	101	.....	.....	...

This Table indicates that, up to a speed of forty-eight miles per hour, the *locomotive carriage* in question has an excess of tractive power and of capability to consume fuel, which might be applied in overcoming gradients, or to the haulage of extra carriages of suitable construction for passengers and parcels—

and of this we shall have to speak hereafter. For greater speed, carriages of somewhat different proportions as to weight would—according to our estimate of the resistance—have to be made. But that the speed of sixty miles per hour on level lines, and up to forty miles per hour on lines having ruling gradients of one in a hundred, could easily be attained, there cannot be a question with those capable of examining the matter. My own conviction is, that I have valued the *resistances* of the locomotive carriage too high, and that even of the proportions above given, these carriages are capable of a speed of sixty miles per hour on existing first class lines, with an expenditure of about one-third of the coke now consumed by locomotives performing the same amount of traffic at one-half that speed.

The locomotive carriage has convenient room for thirty-seven passengers, distributed as to classes in any manner that may be found suitable, with a fair complement of luggage. By a judicious arrangement of the number of departures, it is believed that the *omnibus* average of two-thirds the total seats would always be filled, and hence that the proportion of the *weight moving* to the useful traffic done would be as eight to one, when the speed is fifty miles per hour, and this, *with a pressure on the rail never exceeding three tons on each wheel.* This ratio, it will be found, would be reduced to an average of five to one, for trains travelling at speeds of thirty miles per hour. A striking contrast when compared with the existing system.

In order to illustrate the applicability of these car-

riages I have collected some of the evidence of the men best qualified to speak on this subject, as to their views of how railway traffic, for passengers, would be best conducted and promoted. *One opinion* only on the theory of the subject is admissible,—namely, that of all the causes operating to increase traffic by Railways, the *number of opportunities of locomotion* is, next to cheap fares, the most powerful.

In the Report of the Select Committee on Atmospheric Railways, it is said, "It is the interest of companies adopting the atmospheric principle to increase the amount of their traffic, by running frequent light trains, at low rates of fare, by which the convenience of the public must be greatly promoted. By locomotive engines, the power is most conveniently applied by concentrating the traffic in a smaller number of heavier trains."

"Now, when we consider that we surrender to great monopolists the regulation of all the arteries of communication throughout the kingdom, that it depends in a great measure upon *their view* of their interest, *when* we shall travel, at *what speed* we shall travel, and *what we shall pay*, it becomes a material consideration, in balancing the advantages reserved to the public by rival systems, to estimate, not so much what they respectively can do, but what, in the pursuit of their own emolument, they will do."

The conclusions of the Committee were drawn from the evidence of Mr. Cubitt, senior, who considers that the circumstances *least* adapted to locomotion, by the present locomotive engine, are a great passenger traffic, requiring to go at short intervals, and in

great numbers, at great speeds: of Mr. Stephenson, who considered *even* the atmospheric system better applicable to short lines, a large traffic, and numerous departures, than the locomotive engine with its train: of Mr. Brunel, who says, "My principle would be to encourage traffic by dispatching trains at every hour of the day that would suit the different wants of the public. Each train would then contain the number of carriages that experience pointed out to be necessary for the traffic—therefore, practically, it would amount to reducing the number of carriages rather than reducing the number of trains to meet the wants of the passengers. There is an advantage in carrying just that load which your machinery is well adapted for. On the Great Western Railway *five minutes are lost by stopping at a station*, besides the time during which the train is stationary. The difference between the fast and the stopping trains on the Great Western consists *not so much in the actual speed as the loss of time and speed by stoppages.*"

But the following extract from the evidence of *Mr. J. Hawkshaw*, given before the Gauge Commissioners, November 1845, puts this subject still more clearly and forcibly before us.

"Some years ago it was considered that the traffic of the country might be sent along *main trunk lines* of railway, and that two, three, or four large lines would subserve the traffic of the country. Now it is quite clear that these anticipations are likely to be disappointed—that the *fact* will be that railways will extend themselves all over the surface of the country —consequently the traffic will be *split up into various*

streams, and will become a kind of intermediate traffic, *requiring constant interchange and connexion* at various points, and therefore the question of *a large gauge and a large machine, and so on*, to my mind, is a very *much simpler one than it was five years ago.* I think that the absolute necessity of extending railways, now that every road is to have a railway, rather goes to show that it is not wise to make those railways of very large dimensions. The question is not so much what is best for one large trunk railway, running through the kingdom, as what is best as a system, applied to the whole kingdom; and any system which neglected the extension by branches to every town and every village of importance, would, I think, be detrimental to this country.

"For the reasons which I have stated, and also others quite obvious to myself, I am quite sure that the working of railways will become a very different matter, in course of time, from what it is at present; that instead of COLLECTING traffic, and carrying it in very large heavy trains, *the perfection of the system* will be, to have *much lighter and more numerous trains.* I may state, that in my own practice on the Manchester and Bolton Railway, I have generally increased the trains each way, and I do not, and shall not, feel satisfied, until on lines, like that in manufacturing districts, a time-bill will be unnecessary, *and you will be able to go to the station as you look out in London for an omnibus, and be sure that you will get a train within ten minutes of wanting it.* And my impression is, that that will ultimately be the practice of working railways. I believe it will be for

the advantage of the companies themselves very much, and certainly to the advantage of the public.

"In connexion with running very frequent trains, I may state that it is important to consider that a great portion of the expenses of the railway company would not be at all affected, whether you ran 10 or 100 trains a-day. A great portion of the expense of the company would remain the same." Again, to shew how, by implication, the advocates of the system that concentrates traffic more than any other, admit the inconvenience of a small number of trains starting at long intervals, I quote from the evidence given before the Gauge Commissioners by *Mr. Seymour Clarke.* "We carry first and second class passengers by THE PARLIAMENTARY TRAINS, for the convenience of parties who might wish to go to intermediate stations, and who would be less *conveniently accommodated if they waited, because that train, by the regulation of Government, stops everywhere.*" The distinction between the *convenience of the public* and the *interests of the railway company,* are here fortuitously contrasted in the light in which I am anxious my readers should view it, in order that they may arrive at the same conclusions as myself as to the immense public convenience of adopting the Locomotive Carriage, which I shall now prove to be a means of effecting a *vital economy in railway traffic, with an increase of real travelling convenience to the public.*

The Economy of Locomotive Carriages.

The most palpable economical result that will arise from the substitution of locomotion by locomotive carriages, instead of the present locomotive engines or steam-tugs, will be the saving in coke and in engineers' or drivers' wages. By our Table, page 30, it appears that *ten pounds of coke per mile* will suffice to convey forty passengers at thirty miles per hour. Now, with the single exception of the Liverpool and Manchester line—the most frequented line in Britain, there is, as far as I have learned, no case in which less than twenty-six pounds per mile run by the engines is consumed, and the average speed is not more than twenty-five miles per hour, including stoppages. The saving in coke, then, it may be easily reckoned, will be upwards of fifty per cent. for the same amount of passenger traffic done, and *by double the number of trips at present made.* This estimate *includes the work done in overcoming gradients of one in seventy-five*, such as occur in only one main line of railway in Britain.

The saving in engineers' or drivers' wages will arise from the circumstance, hereafter more fully explained, that one man to drive the engine, instead of two, will be a sufficient guarantee of safety. Or, if there be two companies' servants on the train, connected with the engine, there will be no necessity for a guard.

Again, as the WORK DONE by the engines, that is, *the coke consumed* or the *steam used*, will be, on the

average, *fifty per cent. less for a given amount of passenger-traffic effected,* the cost of *repairs* will be diminished in something like that proportion—or say 40 per cent. less cost of repairs when *locomotive carriages* are used. The saving in *oil* for lubrication may likewise be calculated upon being at least 40 per cent.

Now, taking the total cost of *locomotion* per mile run by passenger trains to be 10·0d., which, in Britain, it is very nearly, we find that—

	D.
The general charges per mile, amount to	3·5
The coke per mile,	4·0
Repairs per mile,	2·5
Total,	10·0

The above estimated savings being effected, we should have, as the cost of effecting the same absolute traffic—

	D.
General charges, viz., wages, cleaners, oil, &c.,	2·1
Coke,	2.0
Repairs,	1·5
Total cost per mile,	5·6

The miles run by the passenger engines on the Eastern Counties Railway, from 4th July 1847 to 4th January 1848, was 824,638. According to the above estimate, the saving on this amount of mileage, by substituting locomotive carriages for the existing system, would be £15,118, 7s. $3\frac{2}{10}$d., or upwards of

£30,000 per annum. The mileage of passenger engines on the London and Birmingham Railway, the Great Junction, the South Western, the London and Brighton and South Coast Railways, are from 1,000,000 to 600,000, or 3,500,000 on all of these; and therefore, a saving of upwards of £120,000 per annum, in this department alone, might be effected on these lines.

If we take into consideration the wear and tear of the carriages, another important item of saving is effected. The cost of working and repairing carriages at present, is said to be very nearly *2d. per mile run by the trains.* This *wear and tear* depends on the construction of the carriages, and on the number of carriages, waggons, &c., in a train. *The lighter the carriages, and the fewer carriages there are in a train, the less the wear and tear.*

Without attempting to estimate the probable saving on this item, I may remark, that the question of the construction of carriages as respects their strength, which for the same principle of construction regulates the weight of frames, springs, axles, and body, is also intimately connected with the question of the efficiency of the train. It is *prima facie* evident, that as the number of carriages in a train increases, the initial effort required to overcome the inertia increases, and thus the propagation of the tractive power of the locomotive from carriage to carriage, through the drawing springs and chains, has to be effected more rapidly—so rapidly, in fact, as to amount to a shock; this is in starting. When a train has to be stopped the circumstances are an-

alogous—the number of brakes applied is very limited—the *vis viva* of the individual carriages has full play—and the train of carriages is brought to rest only after a series of oscillations of the springs of each, more or less violent, has absorbed the mechanical effect expended initially, in bringing them up to their speed.

Mr. Brunel, in reference to this point, gives his opinion as follows:—"The carriages on the South Devon will receive less rough usage, and may be made more perfect than on a locomotive line." The South Devon is or has been worked as an atmospheric line, on which the traffic was to be regulated, so that small frequent trains should effect it.

Mr. Hawkshaw says,—"By frequent trains there would be a considerable saving in the wear and tear of the carriages and waggons. We find now, on the Manchester and Leeds Railway, that the waggons are torn almost to pieces; the chains are constantly breaking; and the repair of these waggons forms a most serious item: in *consequence of so many of them being linked together, they are greatly injured.*" The greatly increased wear and tear of carriages, waggons, &c., on lines using the modern locomotive system, compared with that where horse traction was formerly in use, is thoroughly appreciated in those districts where the transition has taken place more recently, as also in those where the speed of the trains of waggons has been increased, for the sake of the further use of the rails for passenger traffic, as an ulterior object.

Mr. Stephenson, it is true, has said, that "a light

carriage is more liable to get off the rails than a heavy one;" but I cannot find anything in the weight of the carriages, *per se*, affecting their tendency to leave the rails; though it is evident that if in a given train there be any one very light carriage, there is a risk of the motion of that carriage being disadvantageously affected by that of the heavier carriages. When a carriage comes to be loaded with one ton on every wheel, nothing but a dislocation of the road, such as would throw the carriage off, supposing it were double or triple that weight, would interfere with its continuance on the rails, *the relative elasticity of the springs* being supposed equal. The dislocations of the road increase as the insistent weight on the wheels increases; and, therefore, within any contemplated limits of the insistent weight to be brought on carriage-wheels, true mechanical reasoning would lead to the conclusion that a *heavy carriage is more liable to get off the rails than a light one.*

This objection to light carriages is here controverted, because the notion that it is a true one evidently pervaded the opinions of engineers at the period that *Mr. Samuel's Express Carriage* was brought before the public, and it is to this Express engine's success that we are indebted for the introduction of Locomotive Carriages on Railways. Mr. Samuel had, I know, to contend with much prejudice of opinion of older engineers in getting his notion carried into practice; and it cannot be too frequently mentioned, that, confident in the truth of the simple physical and mechanical principles involved in his idea of light locomotive carriages, Mr. Samuel, very much at his own expense and

risk, constructed the engine, which, we have above endeavoured to show, is destined to make a revolution in our Railway Mechanism, and to be the beginning of a really sound system of railway traffic. And I repeat, that light carriages are not more liable to get off the rails than heavy ones, because it may be assumed, that if *additional* carriages have to be put to the locomotive carriage, these will or may be constructed with due regard to diminishing their weight, and that instead of the masses of iron and brass and wood, so prodigally used in the present framings, springs, and buffing apparatus, we may hope to see railway carriages rivalling those constructed for the road in lightness and strength, and that instead of having 3 tons of insistent weight to carry as many tons of passengers, less than one-half of this will suffice.

If the saving in *locomotive expenses* be likely to prove of importance to the railway interest, the economy in the MAINTENANCE OF WAY that will accompany it, cannot fail to be of still greater importance. Those most directly interested are pretty well alive to the manner in which this question has been "blinked" hitherto in the half-yearly reports of railway companies. Still, a brief statement of facts on this point will not, I conceive, be considered irrelevant here.

Mr. Stephenson, in his evidence before the "Select Committee on Atmospheric Railways in April 1845," says,

"The maintenance of the London and Birmingham Railway was originally let for £340 per mile; that was the estimate, including every species of responsibility for slips of all kinds.

Of that amount I imagine that not more than £150 per mile has been spent in keeping the road in order in the upper works, that is, the rails; the rest has been absorbed in repairing the slips of cuttings and embankments, repairing bridges, fencing, painting, &c. The repairing of the North Midland was let by contract—that was merely *the upper works of the railway, with the bridges*—that was let at £119 per mile. The great North of England line is kept in repair by the company. I do not think they let, and I do not know what it costs, but the maintenance of locomotive lines of railway will, in my opinion, sink down to about £120 per mile. That is rather more than the Midland is let for; but it greatly depends upon the material. When the railway is in a clay country the subsidence goes on very rapidly for three or four years, and then it gets stationary.

Q. 1554. Does this include the change of rails as they get old?—A. The £340 included every thing—sleepers and all.

Q. 1555. Is not the North Midland a new line?—A. It has been opened four years.

Q. 1556. You cannot expect that there would be much charged in that case for change of rails?—A. No; but the contractor has taken that upon himself.

Q. 1557. But in taking the contract he had not reason to expect any great outlay for the renewal of rails?—A. No.

Q. 1558. Do you suppose that he would undertake that same contract twelve years hence, when the rails had begun to *wear*?—A. I am inclined to think he would.

Q. 1559. Have you any experience of the wear and tear of rails upon the Birmingham?—A. Yes; I have some. We had some very light rails originally—about fifty pounds to the yard. They proved *too* light. There were about ten or fifteen miles, which wore away in a short time; but they were of bad material. Since they were taken out, at which period I should begin to reckon, we have had no actual wear and tear of rails, *but we very shortly shall have.* What rate it may be I do not know. I have, in making some estimates for the sake of valuing the poors' rates for lines of railway, been called upon to estimate what will be the wear and tear, and I have assumed that the

rails will wear away in twenty years, and the locomotive engines wear out in ten years. It is not an accurate estimate; it will depend very materially indeed, upon both the velocity of the trains and the nature of the traffic.

Q. 1561. In working a railroad we may take it for granted, that in the course of twenty years the whole of the rails must be replaced?—A. I should say so; that will be a safe calculation."

In October 1848, three and a half years after the above evidence was given, Mr. R. B. Dockray reported on the construction of permanent way on the London and Birmingham (or *southern division* of the London and North Western) Railway, "*with the view of determining the best mode of carrying out the renewals on this railway*, which have become necessary at a period of time earlier than he (Mr. D.) had anticipated, consequent upon the comparatively new circumstances of the great increase not only in the weight but in the speed of the engines." This confirms, in a remarkable manner, the general opinion given by Mr. Stephenson to the Parliamentary Committee above mentioned, and afterwards to the Gauge Commissioners, when he stated that "the limit to high velocities would be found, not in any particular gauge, or in the evaporating power of the engines, *but in the economic endurance of the permanent way to bear the additional weight which must, as a matter of necessity, accompany every increase of speed.*"

In Mr. Dockray's report the following significant passage occurs, p. 3. "The rapid deterioration, however, about which there can be no doubt, raises the question, whether the speeds already attained have not approached the economic limit to which Mr.

Stephenson refers ? If this latter be the case, railway companies must look to a *considerably increased outlay in the shape of renewals of permanent way. It may be financially disguised for a time, but sooner or later it must be met, as a regularly recurring charge.*"

Again, p. 4, Mr. Dockray says, "It is evident *that in all renewals increased weight of rails, and increased dimensions of the materials generally, must be adopted to meet the increased duty required.*"

Accordingly, Mr. Dockray's report concludes with the recommendation of a new system of railway superstructure, for which the following is the estimate for a double line, according to Mr. D.'s schedule of prices :—

Rails (100 lbs. per yard, at £10 per ton,)	£3141	4	0
Screw-bolts at joints,	96	8	0
Fangs for do.,	93	17	4
Spikes,	93	17	4
Wrought-iron chairs,	39	12	0
Transverse sleepers,	1161	12	0
Longitudinal do.,	492	4	0
	£5118	14	8
To which I add—Fencing,	180	0	0
Labour in laying,	88	0	0
Total cost per mile, *double line*,	£5386	14	8

My estimate of the annual depreciation of the above is as under :—

Rails, 15 years' purchase, *half value*,	£104	14	1
Screw-bolts, Fangs, Spikes, and wrought-iron chairs, 10 years' purchase, *half value*,	14	2	8
Sleepers, 7 years' purchase, *no value*,	118	2	7
Fencing, do. do.,	14	10	0
Bridge repairs and incidental expenses,	40	0	0
Annual depreciation,	£291	9	4
Add *labour* for maintenance,	85	10	8
Total annual cost per mile,	£377	0	0

I shall offer no comment on this result.

The following is another statement of the cost of laying the permanent way, per mile of double line, on the usual construction, and also of the *annual depreciation, as derived from actual experience*:—

235 tons, 15 cwts. Rails, (75 lbs. per yard,) at £10,	£2357	10	0
59 tons, 15 cwts. Chairs, (27 and 17 lbs.) at £6, 10s.	388	7	6
3520 Sleepers at 5s.,	880	0	0
7040 Keys at £6 per 1000,	42	5	0
7 tons, 5 cwts. Spikes at 14s.,	101	10	0
3520 yards Fencing,	180	0	0
Labour in laying road,	88	0	0
	£4037	12	6

Depreciation.

Rails, 15 years' purchase, half value,	£78	11	8
Chairs, 20 do. do., .	9	16	2
Sleepers, 7 years' purchase, *no value*,	125	14	4
Fencing, 7 do. do., .	14	10	0
Keys, 4 do. do., .	10	11	3
Bridge repairs and incidental expenses,	110	0	0
Annual depreciation, . .	£349	3	5
Labour for maintenance, .	85	13	9
Total annual cost per mile,	£434	17	2

These facts may be "financially disguised for a time," but "where sin is, there shall sorrow be to answer for it." Is there a Railway Company in Britain that has provided for the "evil day" when "*renewals*" of the permanent way at a cost of from £4000 to £5000 per mile, will have to be effected? It is quite certain that there is not one Railway Company whose sinking fund has embraced this large item. Amalgamations, purchases, leases, and such like "*dodges*," have been freely entered into, and these have facilitated the "financial disguise." Mr. Dockray has removed the mask. Mr. Adams' embodiment of Mr. Samuel's express engine into a *locomotive carriage*, helps Railway Engineers and Directors out of their difficulty, and affords a new hope to railway proprietors, that their property may realize something even of their more sanguine expectations.

The "*duty required*" of the permanent way of railways is not difficult to state. ACTION AND REAC-

TION ARE EQUAL AND OPPOSITE. The action of the driving wheels on the rails is twofold ; it is vertical, —crushing, or cross-straining the rails, by reason of the weight of the locomotive ; and horizontal, by reason of the motion of translation which they serve to transmit to the train to effect the traction. In order rightly to appreciate this latter action, the driving-wheels must be considered as toothed-wheels, with an infinite number of teeth, and the rail as a rack of the same kind into which the toothed-wheel works. The wheel *has to take a horizontal retrograde motion at the point of contact with the rail,* and pushes horizontally, in virtue of this effort, against the asperities or *teeth* of the rail, and this *horizontal effort is equal to the tractive power which the engine develops* in moving the whole mass in motion, or equal to the *resistance of the whole mass in motion.*

Hence, it is evident, that for every pound by which the resistance of the train is greater, the horizontal strain on the rails is so much increased. Every resistance which operates on the train—friction, gravity, the resistance of the air—reacts on the rails through the driving-wheels : for, for each of these the engine has to develop an increased motive force, and must therefore have a greater *bite* on the rail, that is, exert a supplementary effort at the point of contact, equal to the resistance to be overcome.

It is unnecessary here to investigate the action of the wheels, other than the driving-wheels. The tangential effort of *the rails on the wheels of the carriages* being measured by the effort necessary to overcome

the friction of the axles in their boxes, is evidently very small for each of these—insignificant, in fact, in comparison with the action of the driving-wheels, by means of which the whole external resistance of the locomotive and train are overcome. The *normal action* of the wheels rolling over the rails is proportional to the weight bearing upon them. The normal action of the driving-wheels must therefore be greater than for any other wheels, and the degree of depreciation, suffered under the *weight* on them, depends on the relative strength of the rails, and on the manner in which the permanent way is upheld. If the rails, sleepers, &c., be increased in weight or stiffness, in proportion to the weight on the driving-wheels, as we have already remarked has been, to a certain extent, the case, the wear and tear under the normal pressure may be kept a constant quantity; but the deformation of the way,—by breaking down of the joints, dislocation of the chairs, compression and dispersion of the ballast,—increases in a rapid ratio as the insistent weight increases; and hence, it is undeniable, that both as regards the horizontal strain and the vertical strain on the rails, the less the power exerted by the engine, and the less the weight on the driving-wheels, the less the *duty required* of the permanent way.

The *duty required* of the permanent way is proportional to the *tractive effort* developed on the rails. Now, according to the *indicator* results we have reported, and the tabulated calculations at page 30, the tractive effort of locomotive engines and of

the locomotive carriages, for effecting the transport of a train of 80 passengers, stands thus :—

Narrow-Gauge.	Broad-Gauge.	Locomotive Carriage.
Gironde.	*Great Britain.*	*Enfield.*
1600 lbs.	1500 lbs.	600 lbs.

or, the "*duty required*" of the permanent way

for the locomotive carriages being .	1
that for the Gironde and train is .	2.66
that for the Great Britain and train is .	2.50

It is only after much consideration that I venture to assert the *direct applicability* of this reasoning. Assuming it to be true, it indicates that a *sinking fund, less by upwards of* £220 *per mile per annum*, would suffice for the maintenance of way, if the locomotive carriages were introduced, instead of the present rasping, crushing, lumbering locomotive engine. I allude here to the *passenger locomotive engines*, having from nine to thirteen tons on the driving-wheels, and going at a speed of thirty miles per hour. *Goods' engines*, with four or six wheels coupled, taking along trains of 200 to 300 tons gross weight, at ten to fifteen miles per hour, are admirable machines, which no engineer can see without feelings of pride and exultation. Every part of the mechanism—locomotive engine, tender, rails, and train of waggons—is then doing an amount of *duty* which ordinary materials can withstand.

Even as regards the item for *repairs of bridges, and incidental expenses of slopes*, &c., the same reasoning is correct in principle. Mr. Brunel, in his

advocacy of the atmospheric system, alludes to this circumstance in the following terms :—

"As regards cuttings and embankments, thinks many of the slips are caused by the vibration produced by the passage of the trains, and that vibration is principally due to locomotives.

"The mode of construction of the locomotive, is in every respect more calculated to give violent blows than the mode of construction of the railway carriages. The springs upon the driving-wheels of the engine cannot be allowed to be so free and act so much as the springs for the carriages, and the blow given by the driving-wheel of the engine, when it meets with any irregularity on the railway, is almost as great as if there were no spring at all. Whilst the blows from the wheels of the carriages is very considerably less. The weight of the *wheels alone*, which of course is not affected by the spring at all in the locomotive engine, is very considerable, *several tons*, whereas the weight of carriage-wheels is not one. And the action altogether of the locomotive engine is much more direct, and produces much more vibration than that of the carriages, and I believe, that by avoiding that, that the works will stand better, or in other words, may be constructed lighter."

For the present it must suffice, that I merely indicate some of the other sources of economy that will arise from the adoption of LOCOMOTIVE CARRIAGES, with *light additional carriages in cases of an average speed of thirty to forty miles per hour.* First, then, there may be effected an economy in STATION ROOM and in STATION SERVANTS—provision being made for the despatch of forty to fifty passengers at quick intervals, instead of 150 to 250 at more distant intervals—few servants being constantly occupied, instead of a large number for a small portion of their time ; and second, the *guard* may serve as money-taker, and hence a great expense in road-side stations may be avoided.

The convenience to the public I consider quite unquestionable. Mr. Hawkshaw's excellent notion may in fact be perfectly carried out. Every advantage in this respect that the advocates of the atmospheric system put forward, as to result from its introduction, may be *actually* realized by the LOCOMOTIVE CARRIAGES, which I consider it never can be by the atmospheric or vacuum pipe.

The only other point in which I have to examine the locomotive carriage, is its relative safety. In this respect it is, or may be made, more perfect than any railway mechanism hitherto suggested that has come under my notice. Its merits are in this respect summed up in Mr. Samuel's words, by stating that "it will be EASILY STARTED and EASILY STOPPED." Accidents to passengers usually happen by reason of the unwieldy nature of the trains, which it is impossible to start quickly, so as to get out of the way of an impending collision, and impossible suddenly to stop, owing to the huge *disconnected mass* in motion; and again, when the locomotive train is suddenly stopped, as by the engine getting off the line, the *collapse* is productive of fearful mischief.

The theory of this part of the subject requires a moment's elucidation. It has been overlooked. It has been mistaken. It is, however, very simple. The law of the horizontal motion of bodies retarded by friction, is, that the space through which a body, endowed with a certain velocity, will pass, before being brought to rest, *is equal to the quotient of the initial velocity squared, divided by the product of twice the coefficient of friction (adhesion) into the coefficient of*

gravity. The space in question is *absolutely* independent of the *mass* (mechanically speaking) of the train, or of the body in motion. It depends essentially on the *amount of the weight of the train brought to bear so as to increase the adhesion.*

Thus, suppose a train composed of a locomotive engine weighing twenty tons, a tender weighing eight tons, and of ten carriages weighing each five and a half tons, to be going at thirty miles per hour, and requiring to be stopped as soon as possible, a brake would, in ordinary cases, be applied to the tender's four wheels, and to one carriage ; or thirteen and a half tons of the eighty-three tons in motion would be used as a friction brake. The adhesion —the *coefficient of friction*—we shall still suppose to be one-seventh = 0·143. The minimum distance within which such a train would come to rest, is, by theoretical calculation, very nearly 420 *yards*, whereas, had it been possible to apply the brake to the whole weight in motion, that is, to all the wheels—to the locomotive, and to all the carriages—it would have come to rest after passing through a space of *seventy yards.* Were it even possible to apply the brake to the locomotive and tender, so as to make the whole of *their* weight available for friction, the train would stop after passing through a space of about 200 yards. The brake cannot safely be applied *at once* to such a *mass* as a locomotive train, and hence, *practically,* greater distances are required for *bringing up* a train than the theoretical calculation given.

For the locomotive carriages, the arrangement of

the framing is such, that the whole weight of the carriage can be brought to bear at once to produce friction; and therefore, from a velocity of thirty miles per hour, these carriages could be brought to rest in seventy yards; and even from a velocity of sixty miles per hour, the carriage *could be brought to rest in a distance of* 250 *yards.* To bring an ordinary locomotive train to rest from a speed of sixty miles per hour, would require the application of the brakes to the tender and one carriage over a space of 800 yards, or nearly half a mile.

The advantages of the small *mass* of the locomotive carriages are nearly as prominent, in reference to the facility of starting them with considerable speeds, as are those of their connectedness or *uniqueness* in reference to facility of stopping them.

These properties of the locomotive carriages, and of the trains that in any ordinary circumstances would be in motion under the system they will lead to, have (besides the comparatively great guarantee against collisions they give to this mode of conveyance) the advantage of allowing of many more stoppages at intermediate points on the line, *without material loss of time.* The facility of stopping and starting likewise gets over the difficulty of *curves.* The locomotive carriages may be stopped, or nearly so, and taken slowly round sharp curves, *without any material loss of time.* In short, the locomotive carriage seems to open up an *avenir* in railway travelling, far excelling in every essential to the convenience and economy of public traffic, the present locomotive engine system.

There may arise difficulties in the minds of railway-traffic managers, as to the manner of conducting traffic with frequent departures at various rates of speed; but the men who have brought the present system to work well will have, I believe, a light task in developing the locomotive carriage systems. I therefore close here this attempt to lay before the public in general, and railway engineers and directors in particular, the advantages of locomotion by locomotive carriages, instead of the present expensive system of steam-tugs.

My friends will give me credit for having conscientiously investigated what I took in hand; and if I be mistaken in any calculation I have made, or in any notions I may have adopted, let my readers believe of their Author that—

Non fumum ex fulgore sed ex fumo dare lucem cogitat....

APPENDIX.

No. I.

In mentioning the name of Hancock in reference to the successful use of locomotive carriages on common roads, I mean not for an instant to deny the equal, if not greater, honour due to Mr. Goldsworthy Gurney, Sir Charles Dance, Colonel Macerone, and Mr. Squire.

A glance at the history of locomotion by locomotive carriages cannot fail to be interesting at this moment, confining the retrospect to within the period when locomotive carriages actually conveyed passengers on roads.

In 1825, a patent was granted to Mr. Goldsworthy Gurney for propelling carriages by steam on common turnpike roads. The novel and difficult nature of the mechanism presented numerous obstacles in practice, which required considerable time, and a succession of extensive trials and experiments, to overcome.

In 1826, Mr. Gurney's carriage "went up Highgate Hill, and to Edgeware, also to Stanmore, and went up Stanmore Hill and Brockley Hill, and against all these hills the wheels never slipped." This carriage ran to Barnet, and went up all the hills to Barnet in 1827, with only one wheel attached or fastened on to the axle; and was run for eighteen months experimentally in the neighbourhood of London. In 1829, "this carriage went to Bath, and over all the hills between Crawford Bridge and Bath, and returned, *with only one wheel attached to the axle*, an additional passenger carriage, taken *in train*, having broken in the first onset, and was not repaired until after its return.

The locomotive carriage was also injured slightly at Melksham, in consequence of a riot there. There were two days' delay at Bath to get this injury repaired; but the return journey from Melksham to Crawford Bridge, a distance of eighty-four miles, was performed in ten hours, including stoppages.

In February 1831, Mr. Gurney having completed three steam-carriages for Sir Charles Dance, that gentleman commenced running one regularly on the road betwixt Gloucester and Cheltenham, and continued so to do for four months, from 21st February to 22d of June. In this *first attempt*, 315 journeys were successfully made, 3000 persons were carried, and nearly 6000 miles travelled. The distance, nine miles, was performed in fifty-five minutes on the average, and often in forty-five minutes. No accident happened to any person whatever. The engines were never out of order, and were as perfect when they ceased running as when they commenced. It was considered then to have been ascertained that "steam-carriages can be worked profitably so as to carry passengers for one *half* of the prices then charged by horse-coaches."

On the 12th of October 1831, a Committee of the House of Commons reported, that they "considered the practicability of travelling by locomotive carriages upon ordinary turnpike roads to be *fully established*;"—that "*tolls to an amount* which would utterly prohibit its introduction had been imposed;"—and that they "recommended legislative protection" (not in the recent sense of the word) "to be extended to it with the least possible delay."

The protection here recommended was against the enactment of several Bills, hastily passed through Parliament, laying prohibitory tolls on steam-carriages, amounting even to £2 for each time the carriage should pass. The "agricultural interest" were blamed by Sir William Molesworth, who presented and ably supported Mr. Gurney's petition to Parliament, in April 1834, for these measures of Parliament. The agriculturists reasoned thus, said Sir William:—"Steam-carriages will supersede carriages with horses; consequently there will be a diminution of demand for horses—consequently the same quantity of oats will not be required—farmers will be ruined, and rents will fall." To avert these evils, Mr. Gurney's carriage was vio-

lently stopped by the trustees of the Cheltenham road, and a vast number of Road-Bills were hurried through both Houses of Parliament. These Bills imposed tolls upon steam-carriages of from six to twelve times the amount of the tolls levied upon stage-coaches with four horses. Mr. Gurney immediately petitioned Parliament. A committee was appointed to investigate the subject. "In consequence of the report of that committee, a Bill was brought in to alter the tolls; which Bill received the sanction of this House, and was rejected by the wisdom of the Upper House."

Sir William further said:—"By means of the prohibitory tolls, this nation may be deprived for a time of the advantages which must necessarily result from the employing inanimate instead of animate power. But one may confidently predict, that steam-carriages will run upon the roads of this kingdom, when the names of those individuals will entirely be forgotten, whose ignorance and whose petty interests have induced them to oppose this important application of *elementary* power. That in this country, prohibitory tolls on steam-carriages should exist, is a circumstance of which an enlightened legislature should surely be ashamed."

Sir George Cayley supported the prayer of Mr. Gurney's petition. Sir George said:—"Not from any want of success in his experiments—not from any failure in his carriage—but by Act of Parliament—*by an act and deed,* has he (Mr. Gurney) been wronged, and by an act and deed ought he to be redressed."

Further:—"I believe that they will eventually produce that desirable degree of free and rapid intercourse between all nations which will in time, though far distant, induce one common language and universal peace among the children of men."

Mr. Jephson, Chairman of the Committee on Steam-Carriages in 1831, and who introduced the Bill "for Regulating the Tolls to be put upon Steam-Carriages," concluded an able speech, by saying, that "he trusted the justice and sense of gratitude in the country, towards one whose inventions so well entitle him to the name of a benefactor of his country, will not allow Mr. Gurney to become one of those flagrant instances of national neglect and ingratitude."

Mr. Wallace (of Kelly) trusted Parliament would signally reward Mr. Gurney, as the creator of such an all-important invention as locomotive steam-carriages for common roads.

Mr. C. Buller (honour to his memory!—in this case, as in many others of his short career in well-doing—his speech should be written in letters of gold) considered Mr. Gurney a public benefactor; "and I trust that the House will comply with the prayer of his petition. It has been but too often charged against us, as a national stigma, that we suffer men of talent and science, whatever services they may have rendered to the community by their inventions and discoveries, to lie neglected and indigent;—that in but too many instances we have failed to discover, or at least acknowledge, a man's worth till he *is* dead. * * * * I trust that the House will, in the case of Mr. Gurney, evince that they are really a Reformed House. * * * * In Mr. Gurney's case THE LEGISLATURE HAS INTERFERED, and virtually suspended his Patent, by imposing tolls on his carriages so heavy as to amount to prohibition, AND THIS TOO WHEN HE HAD PROVED, to the satisfaction of all reasonable men, that his invention was one of the most perfect and complete kind. * * * * I think the question should be put at once, under the peculiar circumstances of the case; for I would not have this act of national justice deferred, as has been too often the case, till the object of it has sunk into the inaction of old age, or the oblivion of the tomb."

Of Goldsworthy Gurney it may be said:—

> "He was one
> Of many thousand such that die betimes,
> Whose story is a fragment, known to few.
> Then comes the man who has the LUCK TO LIVE,
> AND HE'S A PRODIGY.—Compute the chances,
> And deem there's ne'er a one in 'venturous' times,
> Who wins the race of glory, but than him
> A thousand men more gloriously endowed
> Have fallen upon the course;—a thousand others
> Have had their fortunes foundered by a chance,
> Whilst lighter hacks pushed past them."
>
> PHILIP, *Van Artevelde*, Sc. V., Act 1.

In the summer of 1831, Mr. Walter Hancock, of Stratford,

completed a carriage. In 1833, Mr. Hancock started a steam-omnibus from the Bank of England to Paddington. It is because I have frequently taken hours from my sleep, after going through night-duty as assistant engineer at the Thames Tunnel, that I might ride on these carriages, that the name of Hancock came more readily from my pen in writing page 55 than that of Gurney. Hancock's carriages ceased to run about 1836. Mr. Hancock, in every instance, exhibited perfect control over his engine, in guiding, turning, stopping, and backing.

On the 26th of April 1834, Mr. Alexander Gordon, civil engineer, Fludyer Street, Westminster, travelled on one of Macerone's and Squire's carriages, five miles from the Patentee's premises, and five miles back again, at the average speed of thirteen miles an hour. But the quickest journey noted by Mr. Alexander Gordon was on the 4th October 1833, to Edgware and back, a distance of sixteen and a half miles, in one hour six minutes and thirty seconds, exclusive of stoppages for water, an average duly performed, for this distance, of *fifteen miles per hour* (on an ordinary Macadamized road.)

This is enough to prove what I have said as to the perfection to which steam-carriages had been brought at the commencement of the railway era.

No. II.

Mr. D. Gooch's answer, as given in "Appendix, No. II. of the Report of the Commissioners of Railways respecting Railway Communication, &c., 1848," H. L. is as follows:—"The resistance of any given train is of course the same whatever may be the size of the engine, and it has been shown that the resistance by friction of the larger engine is less in proportion to the duty performed than the small one. The whole water to be evaporated is therefore less, or, if allowance be made for the extra weight of the large engine, it will be about the same. * * * The coke is the only charge that is practically affected by the size of the engine, and this, as I have before explained, is in

favour of the large one. Taking the actual consumption of coke by two engines, namely, the Great Britain, with eighteen inch cylinders, and the Ixion, with fifteen and three-fourth inch cylinders, the coke per mile, working over the same ground, with nearly the same train, is, for an average of five weeks, as follows:—

	Average Speed in Miles per Hour.	Average Weight of *Train.*	Average Consumption of Coke per Train per Mile.
		Tons.	lbs.
Great Britain, ...	28	85	33
Ixion, ...	28	80	35
Average of all the Engines working from Paddington, . .	28	75	40

"There is, *therefore*, no increased cost in working the light traffic of a railway with the large engines."

With all deference to Mr. Gooch's experience, I think his deduction quite open to doubt, if not untenable. In making the above comparison Mr. Gooch selected "the Ixion as the best of the small engines fitted with an expansive gear, similar to that of the Great Britain." The period over which the average is taken is only five weeks, or probably not more than *twenty trips of each engine.* The weight of train in each is very nearly the same. There was *expansion* gear on the two engines. The *areas of the cylinders were as five to four nearly.* It therefore appears to me much more rational to account for the economy of the Great Britain over the Ixion, and of both over ordinary engines, by attributing it to the greater use of *expansion* than to any absolute influence of the size or weight of the engine. It is to these circumstances *as to the manner of using the steam in the engine* that I attribute the *non-appearance of the effect of increased insistent weight on the driving-wheels,* in Mr. Gooch's "Average Consumption of Coke per train per mile."

No. III.

The experiments of Messrs. Gouin and Lechatelier (Recherches experimentales sur les Machines Locomotives, Paris, Dec. 1845,) show that the influence of the contraction produced by the regulator (or throttle valve) when it is *half open*, is not 5 per cent. of diminution of pressure between the boiler and the nozzles, or cylinder ports, and that the difference between the pressure in the nozzles and in the cylinder is also 5 per cent. as a *maximum, save when the engine is* PRIMING *much.* (The details of Mr. D. Gooch's experiment 16. Sept. 8, 1847, amongst others, illustrates the effect of *priming* in diminishing the tractive power of the engine.)

The experiments on the "Gironde" proved that the mean resistant or *back pressure* in that engine, was equal to 42·5 *per cent. of the effective motive pressure;* that is to say, that if by any means this resistance could be got rid of, *cæteris paribus*, the useful effect of the steam on the pistons would be increased 42·5 per cent.

It is evidently of prime importance to ascertain the cause of this result. One element of this *back pressure* is the cushion of steam retained by the overlap or lead. When, during the back stroke of the piston, the effective pressure of the steam is *null*, the mean counter pressure is not more than 1·4 lbs. per square inch, *reduced to the whole length of the stroke*, or *diagram curve.* In ordinary circumstances, the area corresponding to the counter pressure is greater, because the effective pressure itself is considerable; but the back pressure, reduced to the whole length of the stroke, never exceeds 3 lbs. per square inch, or one-fifth of an atmosphere; now there remains still nearly four-fifths of an atmosphere to account for.

The following is a summary of the preliminary experiments made by MM. Gouin and Lechatelier on this point, and which are sufficient for answering the question.

They commenced by putting a mercurial manometre in communication with the upper extremity of the exhaust-pipe, and they there detected pressures of from 2·4 to 4·4 inches of mercury, according to the size of the orifice.

They then introduced the end of the tube attached to the monometre *into the eduction port, under the slide valve*, and *there* the mean pressure varied from 3·5 to 6·6 inches of mercury. It is necessary to call attention to the circumstance, that this pressure, indicated by the monometre, is a mean *in reference to time:* whilst the back pressure on the piston, deduced from the diagrams, is a mean in reference to the *stroke* of the piston, and that the *maximum* of this resistant pressure takes place at the ends of the stroke, when the motion of the piston is retarded, and about to change its direction. The *maximum* pressure in the eduction port evidently corresponds to the same periods of the piston's stroke, and consequently, if they had measured this pressure directly with the indicator, they would have found still smaller mean values than those above given.

It may, therefore, be admitted that for a *back-pressure* equal to one atmosphere, the pressure in the eduction port, *under the slide valve*, is not more than 6 inches, or one-fifth atmosphere. By adding this fifth to the fifth found as the proportion of the total resistance attributable to the counter-pressure from "*lead*," there remains still three-fifths of an atmosphere unaccounted for. This great amount can be attributed to no other cause than to the resistance of the passage of the steam through the ports in being expelled from the cylinders.

Referring to the experiments made on the *difference of pressure of the steam in the nozzles and in the cylinder*, (Table III., p. 15 of the paper above referred to,) it will be found that when the engine was worked by a driver who kept the water *high* in the boiler, the difference of those pressures amounted to about 10 per cent. of the whole, or for five atmospheres' absolute pressure, the diminution was half-atmosphere. It is not, therefore, to be wondered at, that during the "exhaust," when the volume of steam (nearly doubled by its decreased density, and the steam being loaded with water, *primed* or condensed) traverses a narrow port, (which had been heated during the admission of the steam, and which may, therefore, re-evaporate the drops of water,) the resistance should amount to three-fifths of an atmosphere.

Adopting, therefore, the mean results which have been arrived at, we can estimate in *horses' power* the mechanical effect—

motive or resistant—of the steam in the different phases of its action.

MM. G. & L. have done this for their diagram No. 59, Table VIII. The results are as follow:—

Number of revolutions of wheels per second, .	2·7
Velocity in miles per hour, ...	31·8
Effective *motive* pressure, ...	51·6 Lbs.
Effective *resistant* pressure, ...	15·07 do.
Total motive mechanical effect, . . .	301·6 H.P.
Total resistant, ...	88·1 H.P.
Useful effect on Piston, ...	213·5 H.P.
Mechanical effect due to counter-pressure from "*lead*,"	16·6 H.P.
Do. do. do. in passing ports, . .	54·9 H.P.
Do. do. do. in passing into exhaust,	16·6 H.P.

This example, in which any error is certainly in deficiency, and not in excess, as far as concerns the resistance in passing the ports, and although it is *special* for the *Gironde*, shews very clearly where the *internal* resistances in the locomotive arise. It shews the vital importance, in reference to economy of combustible, of adopting means to facilitate the escape of the steam. It shews, also, what portion of the *back-pressure* is really employed in exciting the *blast*.

No. IV.

In Mr. Stephenson's evidence before the Commissioners appointed to inquire into the gauge of railways, (August 1845,) having been asked, "Do you happen to know the amount of steam expended per mile, or per journey, with the same load at different speeds—say from sixteen to forty miles per hour?" Answers—"I am not aware of any experiment which will admit of any correct answer being given to this question. The experiments which I thought were generally applicable to this case, were made on the Northern and Eastern, to ascertain the expenditure of water with different loads rather than at different speeds; and also to compare the consumption of fuel by an engine worked alone, and by an engine with a load, so as to get the relative proportions of power expended in overcoming the engine, and in overcoming the loads. Those experiments were made for a different object, and I thought at the time the question had reference to that particular point."

Q. 738.—The Commissioners would be glad to have the result of your experience upon that point.—A. I will give it. * * * The experiments were made to ascertain what proportion of coke was consumed for putting the engine in motion alone, and then adding five or six, or eight or ten carriages on, and finding the relative consumption with these loads. *It came out that the consumption of fuel to overcome the engine and tender alone, formed a very serious amount.* * * * I found that the consumption of fuel for drawing the engine without a load was equal to about the consumption of fuel to overcome a load of fifteen carriages at thirty miles per hour; that is, it took as much to move the engine and tender as it did additional to move fifteen carriages. There have been many reasonings on this without considering the precise application of it. A large proportion of the fuel used in moving the engine alone, is consumed in overcoming the resistance of the atmosphere to the pistons. *It will not require more than three or four pounds to overcome the friction of the engine and tender proper*, but requires fifteen pounds in addition to that to

overcome the engine and tender, taking into account the atmospheric resistance to the piston; so that there is always fifteen pounds of pressure of steam in all high-pressure engines absolutely lost. *It is not the friction of the engine;* certainly it is a defect in the engine from its *being a high-pressure* engine; but on no other account. It is not a peculiar loss applicable to locomotive engines alone, but to all high-pressure engines.

Whilst these answers of Mr. Stephenson confirm generally what I have adduced in reference to the *absorption of power by the locomotive and tender*, there are certain points on which Mr. Stephenson's doctrine requires illustration in order to ascertain whether his theory be true.

In the first place, *the proportion of the fuel consumed in overcoming the resistance of the atmosphere to the pistons of the engine* to the whole fuel consumed in the engine, depends on the power the engine may be expending, that is, on the mean absolute motive pressure of steam in the cylinder. Thus, if the mean absolute motive pressure be two atmospheres, then the proportion of the fuel consumed by the resistance of the *atmosphere* to the pistons is fifty per cent. of the whole. If this pressure be four atmospheres, the proportion is reduced to twenty-five per cent., and if it be five atmospheres, or seventy-five pounds mean *absolute* motive pressure per square inch of cylinder, then the proportion is twenty per cent. of the whole. So far the consumption of fuel in the locomotive is to be attributed to its being a high-pressure engine as compared with a condensing engine using equally high-pressure steam: but supposing a condensing engine to use steam at two atmospheres' pressure, and a high-pressure engine to use steam at eight atmospheres', the useful effect of one pound of fuel would be *very nearly equal in the two cases.*

In the second place, our Tables, page 10, show, that besides the atmospheric resistance there is a *back-pressure* resulting from the power required to overcome the inertia of the used steam, to which a great velocity has to be communicated—the losses of *vis viva* in the ports and bends, and the friction in the blast-pipe, and the precise amount of which back-pressure, when compared with the *effective pressure in the cylinders*, is seen from the following Tables: —

NARROW-GAUGE.

Speed in miles per hour.	Effective motive pressure on Piston.	Resistant or back pressure beyond the Atmospheric pressure taken at 15lbs.	Ratio of the Resistant to the motive pressure.
	lbs. per sq. in.		
19·26	45·50	20·40	·45
23·55	36·60	9·74	·27
25·29	37·68	20·69	·55
27·09	36·54	19·12	·54
29·45	33·55	15·28	·45
34·25	32·99	19·98	·60
24·73	49·19	15·99	·32
	BROAD-GAUGE.		
20	20·48	1·23	·06
20	17·35	0·84	·05
25	17·51	1·33	·08
44	25·25	4·39	·17
56	46·07	16·67	·36
60	29·36	9·39	·32

Messrs. Gouin and Lechatelier state, as the general or mean result of their experiments at speeds varying from 20 to 35 miles per hour with the *Gironde*, (after the *overlap* had been suppressed, which it was *not* in the diagrams I have used,) that the mean resistance, during the retrogression of the pistons, was 42·5 per cent. of the effective motive pressure; that is to say, that if, by any means, we could entirely destroy this resistance, the engine, &c. remaining in other respects the same, we should increase the useful effect of the steam on the piston by 42½ per cent. The very great difference in favour of the broad-gauge in this respect is easily explained. I believe, however, that this advantage of the broad-gauge is pretty nearly counterbalanced by the *weight of the engine* involved. This back-pressure, it must be observed, includes the resistance to be overcome in producing the sharp blast required in the locomotive in order to consume a sufficient quantity of coke on a small grate in a short time.

Mr. Stephenson's estimate of "*the friction of the engine and tender proper*," agrees with that of Mr. Brunel, quoted page 17, as to the small amount of it; but Mr. Stephenson's experiments do not serve to exhibit the resistance of the locomotive engine and tender considered as carriages, for anything but a vague opinion, on which essential points, the indicator diagrams and dynamometrical records—referred to in page 10, were necessary. In Appendix II. this subject is further discussed.

EDINBURGH: T. CONSTABLE, PRINTER TO HER MAJESTY.